An in-depth analysis of Hadronic and Glueball Regge Trajectories

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1. Introduction

We present some non-trivial aspects of Mesonic, Baryonic and Glueball Regge trajectories and perform a comparative analysis between them based upon different parameters [1]. The different inbuilt composition of the three seems to serve as a basis for their individual identities. Even the seemingly identical mesonic and baryonic RTs have some intrinsic dissimilarities despite being intimately coherent. The picture of universality of slopes (α~1.1GeV^2) of mesons and baryons is violated. This can be plausible only if the strings joining the quarks have constant string tension (α=1/2$\pi\sigma$), (where σ is the string tension). The hadronic and Glueball RTs do not obey a strict linear relationship between J and M^2 , at all values of J. The String Models predict the linearity of the RTs at high J and nonlinearity at low J. The Pomeron (rightmost singularity in the complex angular momentum plane) may turn up as a possible candidate for the leading Glueball RT.

2. Crossed Channel Forces in Mesonic RT, Baryonic RT and Pomeron RT

Vanishing of crossed channel forces [2] enables us to plot two trajectories together and this is called Exchange Degeneracy (EXD) [3]. When the crossed channel forces vanish, the even and odd signatures coincide leading to overlapping of even and odd trajectories. This gives the EXD conditions:-$\alpha_+ = \alpha_-$ and $\beta_+ = \beta_-$, where α is the position (RT) of simple poles and β is the residue (Regge residue).In the case of mesons, the above EXD conditions are satisfied and thereby the even and the odd parity mesons can be plotted on the same RTs.

Now, we shall talk about the baryon RTs. In the case baryons, the exchange channel forces do not vanish. Therefore, in this case even and odd parity baryons are plotted on different trajectories. We will now discuss about the Pomeron Exchange Degeneracy. The authors [19] explored two different models for the Pomeron and fitted the Exchange Degenerate sub leading RTs to the forward scattering data for certain reactions. They found that Exchange Degeneracy is violated and the amount of violation needs to be estimated.

3. Signature (σ) for Mesonic, Baryonic and Glueball RTs

The signature σ [3] can be either positive or negative. Positive signature implies that equal contribution is given to amplitudes for elastic scattering of particle and antiparticle, whereas vice-versa for negative signature.

Mesonic RT:- Corresponds to particles and resonances for those values of ‘t’(t being the centre of mass energy of the quark-antiquark pair defined as $t \equiv (p_q + p_{\bar{q}})^2$) where it passes integer values (Reα(t)=n) even for σ = + and odd for σ = -.

BaryonicRT:-Corresponds to Re α(t) = n/2=J with signature $\sigma = (-1)^{J-1/2}$

Pomeron RT:- Always corresponds to positive signature σ = +

4. Dependence of the Slopes of Mesons and Baryons on the Fine Structure Constant (α=1/137)

David Akers [4] has showed that the meson RTs are dependent upon a 70 MeV quantum proposed by Gregor [5] and co-related it to the model of Barut [6]. Akers showed that slopes of both meson and baryon RTs are unequal, yet they both show proportionality to the fine structure constant (α=1/137). From Barut’s solution to a relativistic Balmer mass formula, we have

$M = (m_1 + m_2)^2 + 2m_1m_2\, J/\alpha$, where ,$m_1=m_2$=70MeV=0.070GeV.
Slope (meson)= $2m_1m_2/\alpha$=2(0.070)(137)=1.3426 $GeV.^2$ Taking the nucleon to be the starter of the series for the baryon RT, we have $m_1 = m_2 = m_3 = u$ = 315MeV. The quark mass is taken to be 97% of the total mass, the rest being the contribution of the binding energy Slope(baryons)=$[(m_1m_2m_3)/(m_1+m_2+m_3)]\alpha_s$
Where α_s = 137/4=34.25 is the running coupling constant. Therefore the baryonic slope is : Slope (baryons) = $(0.3056)^2(1/3)(137/4)$=1.0662 GeV^2 . the slope of the baryons is less than that of the mesons.

5. String Models for the Mesonic, Baryonic and Glueball RTs

String models are extremely useful for describing orbitally excited hadron states. The strings are relativistic and there is a direct analogy between the string and linearly growing energy and the QCD confinement, which connects quarks by gluon flux tube. A mass less string results in linear RT, whereas a relativistic string with massive ends is not so simply interpreted.

5.1. Mesonic RT:-Olsson Model

Under the WKB [7] approximation for generalized Klien-Gordan with pure vector potential,

$$\alpha' M_n^2 = J - J_0 + (2n+1)\left(\frac{J - J_0}{2J}\right)^{1/2}$$

From the above, we can clearly see that non linearity appears at small J. A linear relationship between J and M^2 appears at high values of J and it is a clear manifestation of the strong forces between constituent quarks and is an immediate consequence of the string picture.

5.2. Baryonic RT:- Sharov String Model

The system is visualized as a configuration in which internal massless points with the speed of light. The configuration can be a triangle which can be smooth or exotic. Sharov [8] gave the formula for E and J as

$$J = \frac{a}{2\omega}\{E - \sum_{i=1}^{3} m_i (1 - v_i^2)^{1/2}\}$$

From the above equations, we observe the nonlinear connection between E and J.

5.3.Glueballs in Soloviev's String Model (SQM)

Sharov formulated a relativistic quantum model in which RTs do not grow linearly, but instead show a faster growth. In his string approach, Soloviev showed that the growth rate is visualized by the exponent 3/2 and the string is rigid. Therby, the Lagrangian is given by an exponential function.

The author [9] discussed glueballs in SQM. He showed that the glueballs which are eigenstates of the quantized simplest closed (elliptic) Nambu-Goto string having quantum numbers $I^G j^{PC} = 0^+ j^{++}$.

The Glueball RTs can be written as

$$\{(j+k)(j+k+2)\}^{1/2} = d_0 + \frac{1}{4\pi\pi} m^2$$

Glueballs which have even spins lie on the leading RT, 2nd daughter RT and so on. Glueballs which have odd spins lie on the 1st, 3rd RT and so on. For large values of j, the RT, $j(m^2, k)$ have the slope

$$j'(\infty, k) = 1/(4\pi a) = 0.452 GeV^{-2}$$

This slope is half the slope of quark-antiquark state. Non linearity is evident at small j.

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